Two-Way Coupled Model Studies of Diurnal Convection Over the Tropical Pacific

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LONG-TERM GOALS

Our long-range objectives are to encourage and facilitate the incorporation of improved aerodynamic bulk formula into operational marine forecast models and demonstrate the marine forecast sensitivity to coupled boundary layer parameterizations.

OBJECTIVES

The main objective of this proposal is to explore the physical processes of the air-sea coupling that may be responsible for accurate simulation of tropical convective cloud systems and SST on the diurnal to synoptic time scales over the western Pacific warm pool. In this exploratory study we propose to examine the model sensitivity to an interactively coupled non-advective upper ocean mixed layer model with a full three-dimensional high resolution atmospheric model. We will explore how changes in the coupled boundary layer parameterizations and two-way air-sea coupling may impact forecast fields.

APPROACH

Observations have shown that the convective cloud systems and precipitation in the equatorial western Pacific have a pronounced diurnal cycle (e.g., Gray and Jacobson, 1977; Janowick et al., 1994; Chen and Houze, 1997). The diurnal cycle of surface temperatures affect the diurnal variation of clouds and precipitation over the warm pool. The diurnal heating of the oceanic and atmospheric surfaces provides favorable conditions in the afternoon for the initial formation of cloud systems; and, as the cloud

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systems grow and decay with time, the diurnal cycle of cloudiness reflects the lifecycle (initiation, growth, and dissipation) of cloud systems.

In this exploratory study, we propose to examine the model sensitivity to an interactively coupled non-advective upper ocean mixed layer model with full three-dimensional high resolution atmospheric model. The atmospheric model we will use is the PSU/NCAR non-hydrostatic mesoscale model (MM5).

WORK COMPLETED

In the first year we focused on investigating the sensitivity of model simulated convective cloud systems to interactively varying SST which is determined by a warm-layer calculation in the COARE flux algorithm (Fairall et al; 1996). The COARE flux algorithm is currently available in the MM5 yet the warm layer parameterization has not been used yet. The warm-layer parameterization is basically a simple version of the Price et al. (1985) (PWP) dynamic instability mixed layer model. The parameterization is initialized by a given SST value at local midnight and then integrates the surface heat, momentum and freshwater fluxes and calculates a diurnal warming layer each time the flux algorithm is executed. This warm layer is added to the initial SST to yield a diurnally varying SST. The parameterization resets the warm layer at midnight local time every day and thus the parameterization is limited to forecasts for 24 hours and is not suitable for long integration and forecast times. However, it is appropriate to use it to investigate the sensitivity of the atmosphere to diurnal SST variability. And, since part of this code is already in place in the MM5, there is only a little code development needed so that we can begin to conduct various model experiments.

RESULTS

We successfully modified the MM5 air-sea flux subroutines to utilize the warm layer algorithm. This was a little bit tricky because of the parallel processing. The diurnal SST is allowed to develop spatially. Each horizontal grid point of SST evolves independently in direct response to the local air-sea flux. The new time-varying SST is then fed back into the air-sea flux calculation at the next time step. This allows for two-way feed backs and true coupling of the atmosphere with this diurnal warm-layer ocean model.

We successfully tested the new warm-layer components in MM5. We used an existing MM5 run as a benchmark with the same initial and lateral boundary conditions from TOGA COARE. We successfully obtained a 5-day model simulation over the western Pacific. Results look very reasonable.

We next ran a few experiments designed to explore how both spatial and temporal variability of SST impacts the distribution of surface heat and moisture fluxes, and in turn the patterns of convection. We reran the MM5 with the warm layer off but the same initial and horizontal boundary conditions. We conducted runs with spatially and temporally homogeneous SST as well as simple SST patterns such as a Gaussian anomaly pattern whose amplitude and spatial scales were modified to look at forecast sensitivities.

We have not yet completed our quantitative analysis of these various experiments. We do observe differences in convective patterns after 24 hours of integration, but it appears that the initial conditions play a large role in setting the large-scale patterns. We will continue our investigation of the differences.

IMPACT/APPLICATIONS

Although this project is quite limited in scope, it has had directly related impact and links to two other projects. First of all, M. Caruso (WHOI) and S. Anderson (WHOI) successfully compiled and ran the MM5 at WHOI. They then applied for and were awarded funds from the Rinehart Coastal Research Center to implement the MM5 at WHOI with a domain covering Georges Bank, Cape Cod and Mass Bay. These model fields will provide some mesoscale context for observations programs including ONR CBLAST and NOPP.

Secondly, S. Chen has been using MM5 to study the ITCZ convective cloud systems over the eastern Pacific. This is a region where recent work has shown clearly the air-sea coupling across the strong equatorial front (i.e., strong meridional SST gradient). S. Chen conducted several one-month-long simulations with various SST patterns to investigate their impact on ITCZ convection. She first used SST from the NOGAPS global analysis fields for August 1997, which represents a warm ENSO event. She then modified the SST field similar to that observed from a cold ENSO event with enhanced meridional SST gradient over the eastern Pacific. This had a clear effect on the ITCZ convection, not only changes in the large-scale convective pattern but also the mesoscale convective organizations (e.g., vertical extent and lifetime of the cloud systems).

TRANSITIONS

We are communicating our results with J. Doyle and the COAMPS team. In addition, S. Chen will be gearing up to run COAMPS locally at RSMAS. This will eventually allow for a comparison of the sensitivity to air-sea fluxes in the COAMPS and MM5.

RELATED PROJECTS

Related projects include the ONR CBLAST, NOAA Pan American Climate Study and TOGA COARE.

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